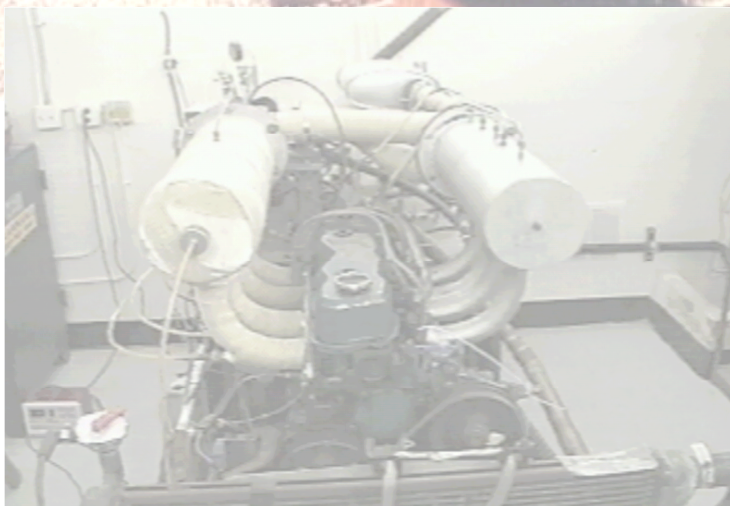
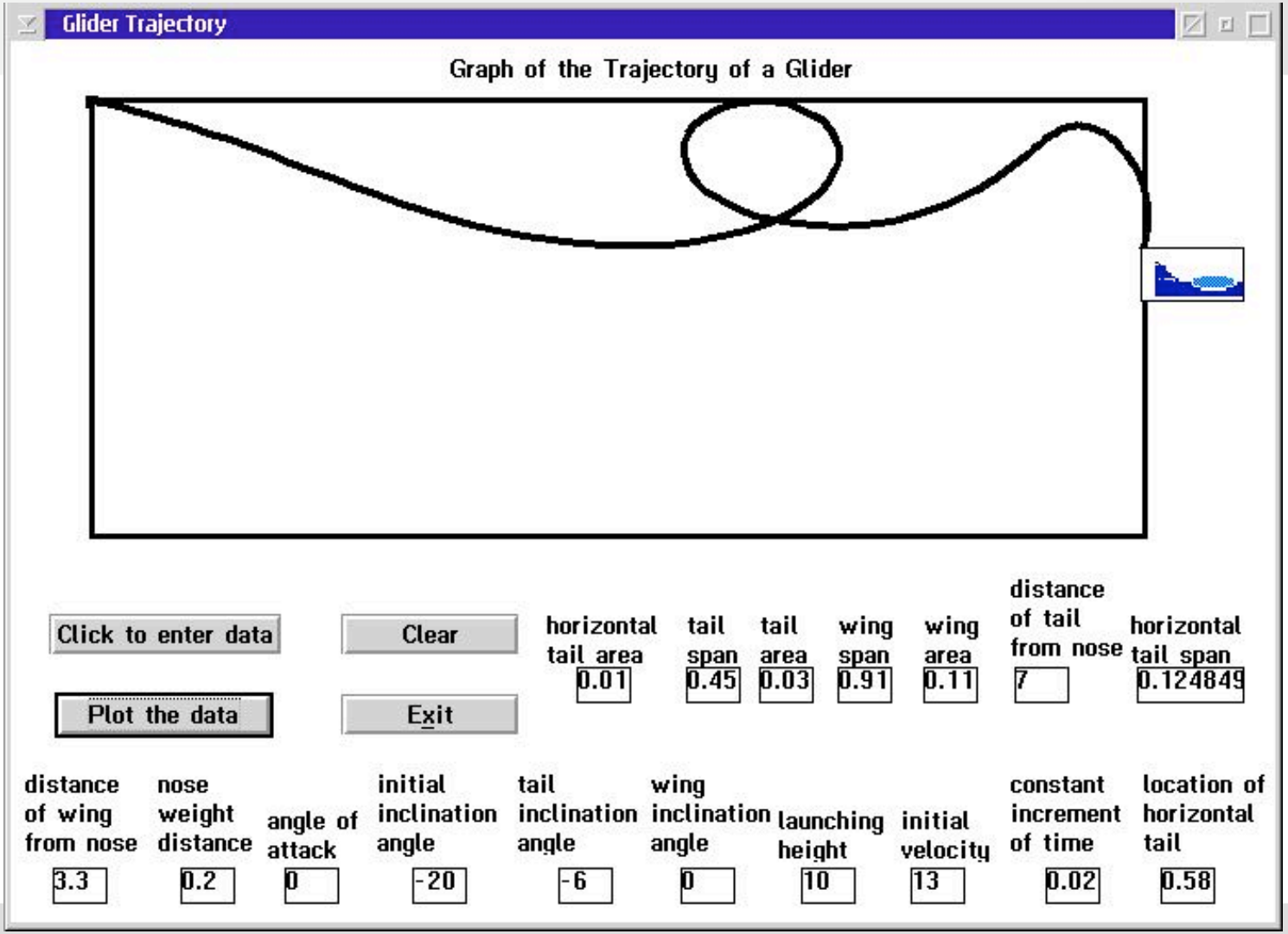
Propulsion Systems (Energy Conversion)



Outline

- Engine Basic Background
- Newton's Law
- Gas Turbine Engines
- Relationships back to Engines that we use.
  - Classification of internal combustion (IC) engines
  - Note: IC sometimes stand for Intermittent Combustion
  - Types of cycles - gas turbine, rocket, reciprocating piston gasoline/diesel
- Relative comparison to other engines

Newton's Law


Glider Trajectory
Graph of the Trajectory of a Glider
Click to enter data
Clear
Plot the data
Exit
horizontal tail area
0.01
tail span
0.45
tail area
0.03
wing span
0.91
wing area
0.11
distance of tail from nose
7
horizontal tail span
0.124849
distance of wing from nose
3.3
nose weight distance
0.2
angle of attack
0
initial inclination angle
-20
tail inclination angle
-6
wing inclination angle
0
launching height
10
initial velocity
13
constant increment of time
0.02
location of horizontal tail
0.58

Newton's Law

$$\boxed{F = \frac{d}{dt}(mV)} \qquad F = ma$$

$$F = \frac{dm}{dt}(V) \qquad F = m\frac{dV}{dt}$$

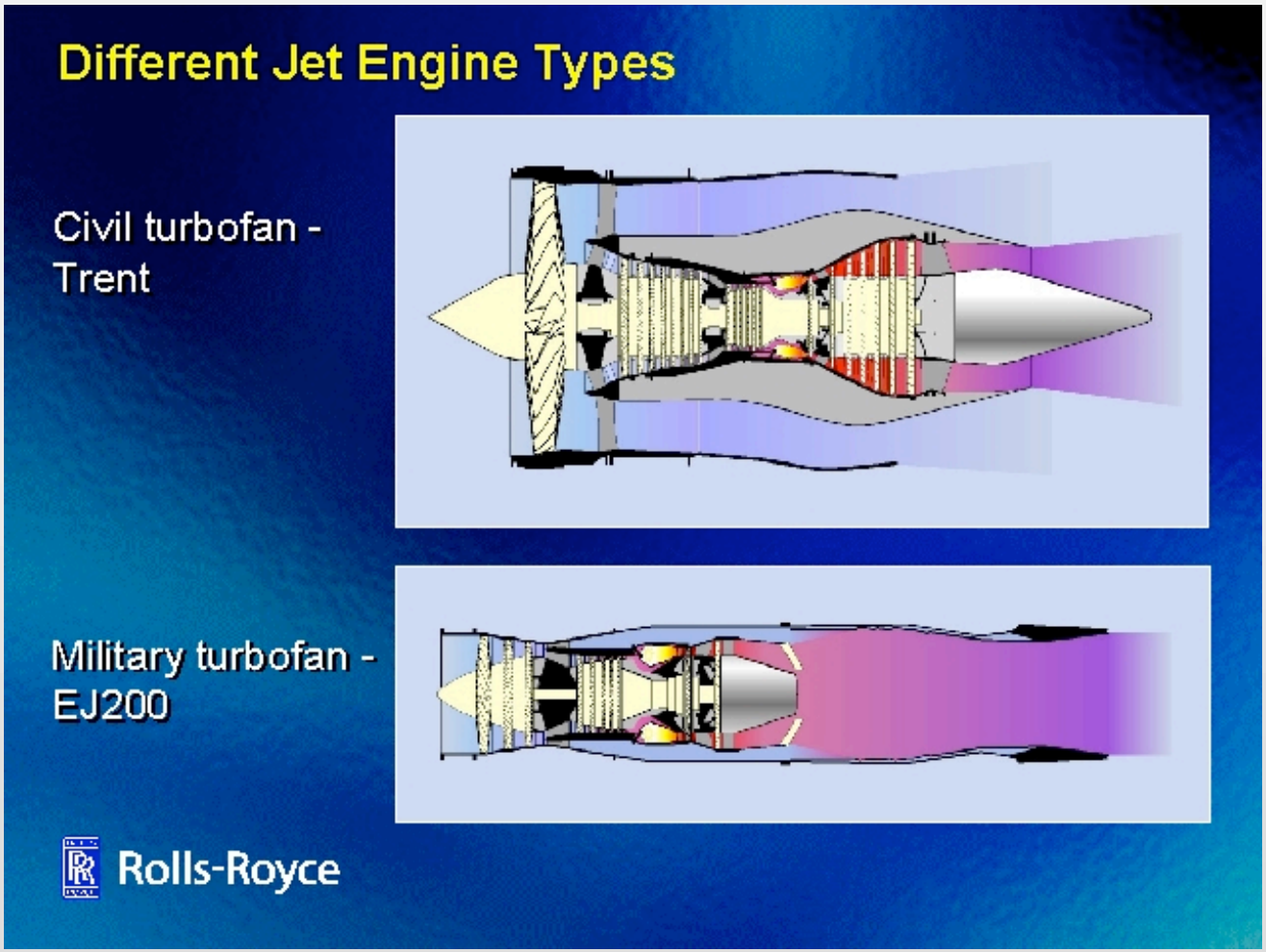
Newton's Law -Engine Guy likes

$$F = \frac{dm}{dt}(V)$$

Generate a large Velocity

Move a lot of Mass

Use of Newton's Law



- Huge m
- Huge V

What Happens Inside??

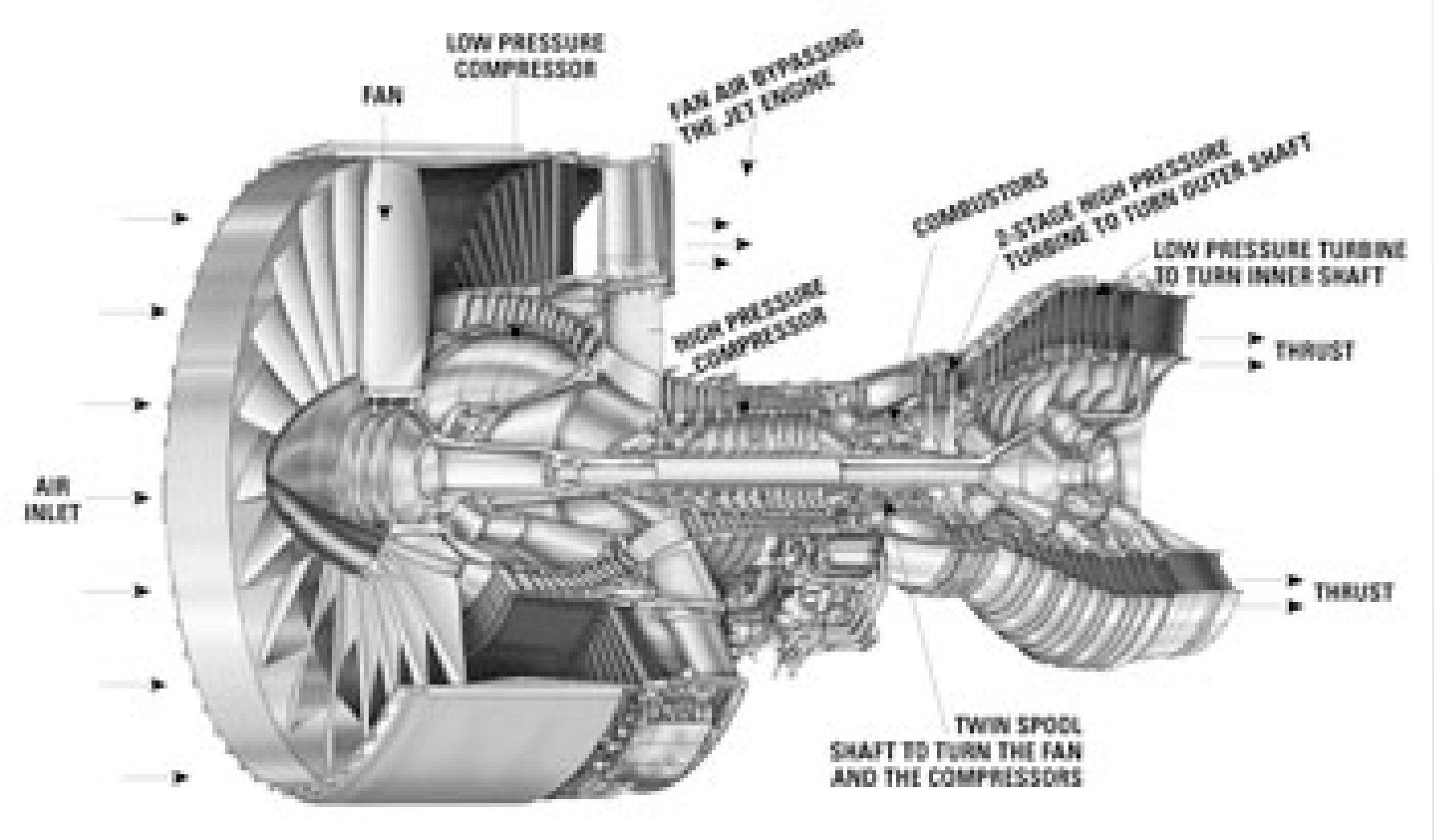
Why? With a global market value of over $200 billion.

Compression -> Combustion -> Expansion(Exhaust)

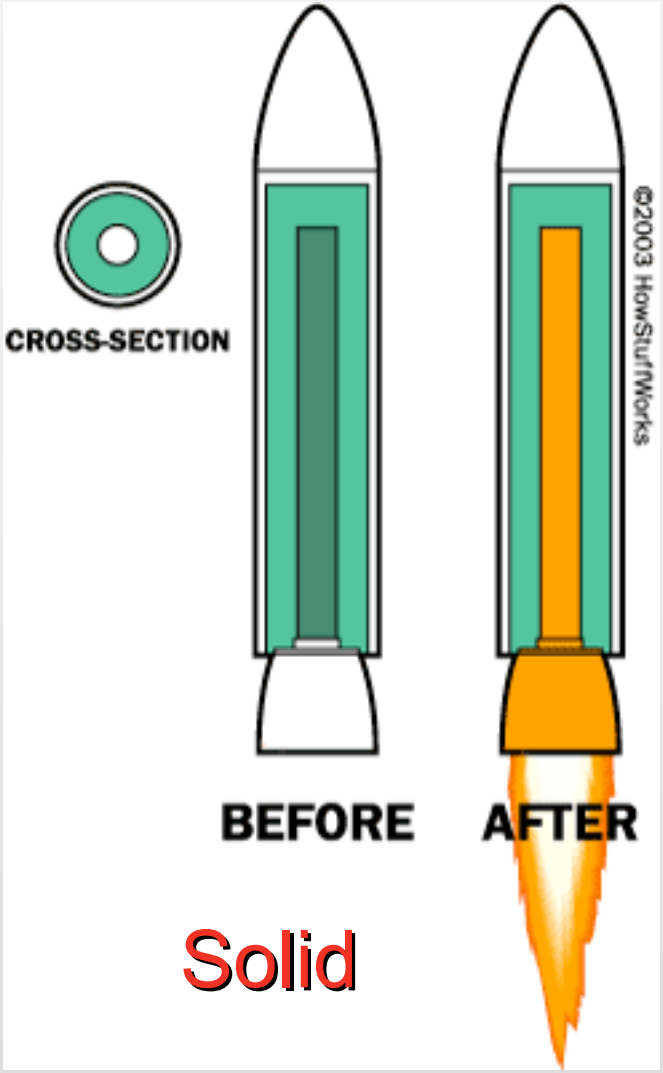
Review of thermodynamics

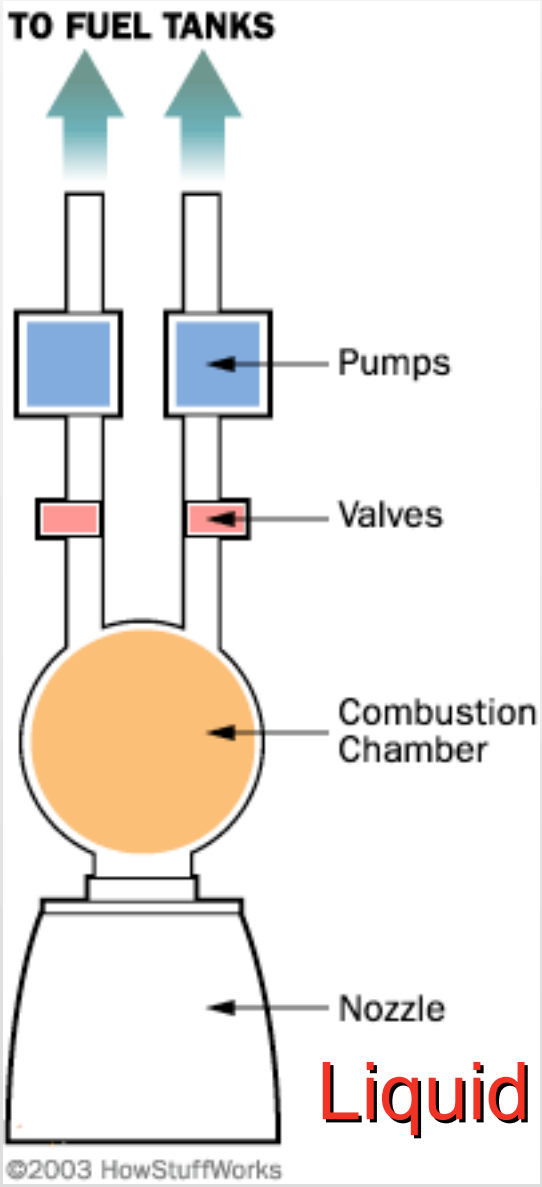
- Almost everything in Engines can be analyzed with
  - 1st Law of Thermodynamics (conservation of energy) - “you can’t win”)
  - 2nd Law of Thermodynamics - “you can’t break even”)
  - Equation of state (usually ideal gas law) - “you can’t even choose your poison”
  - Conservation of mass
  - Conservation of momentum

Turbofan (http://www.howstuffworks.com)

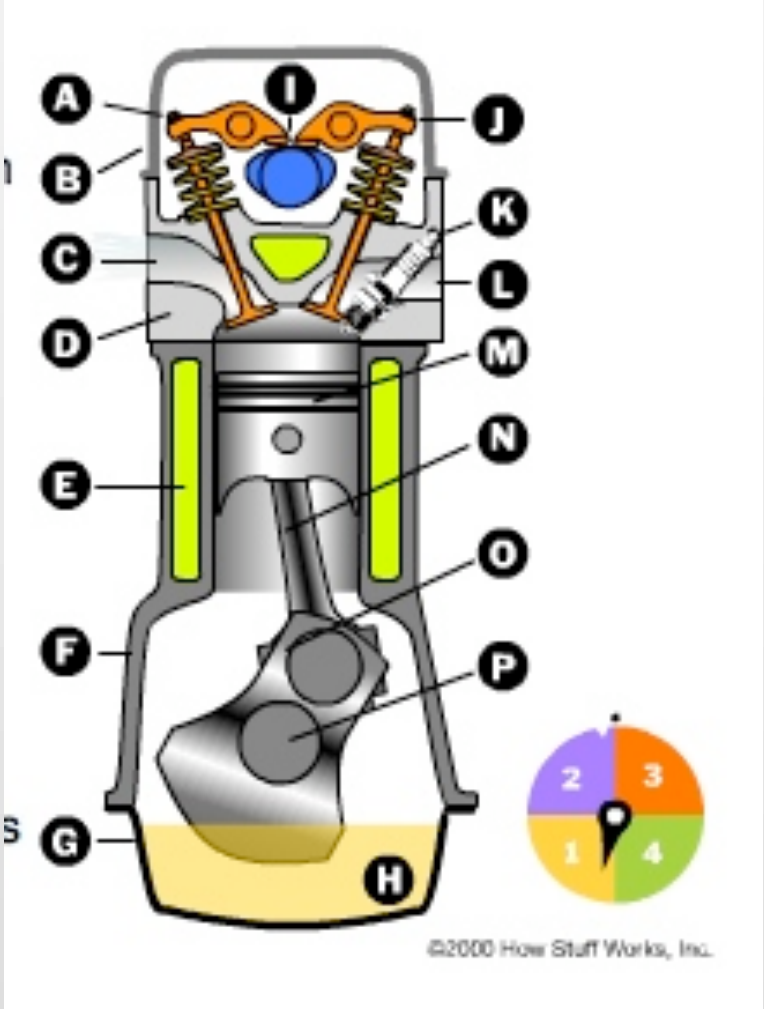


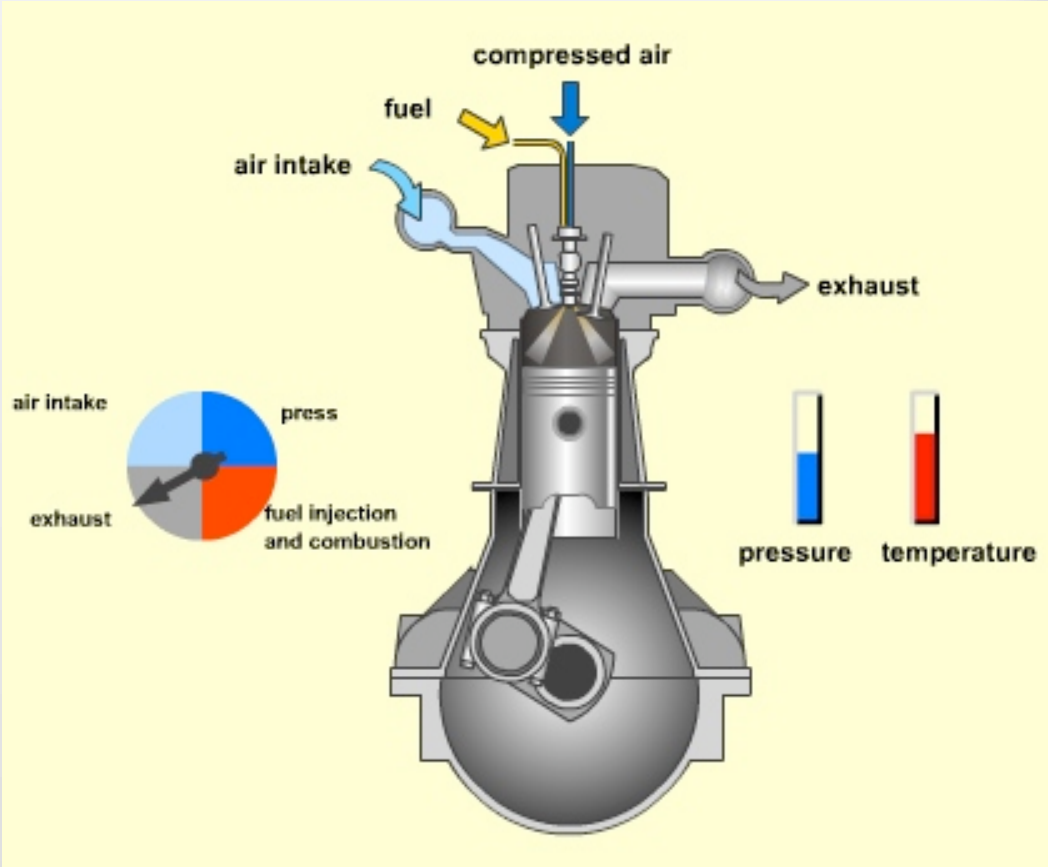
Solid / liquid rockets (http://www.howstuffworks.com)





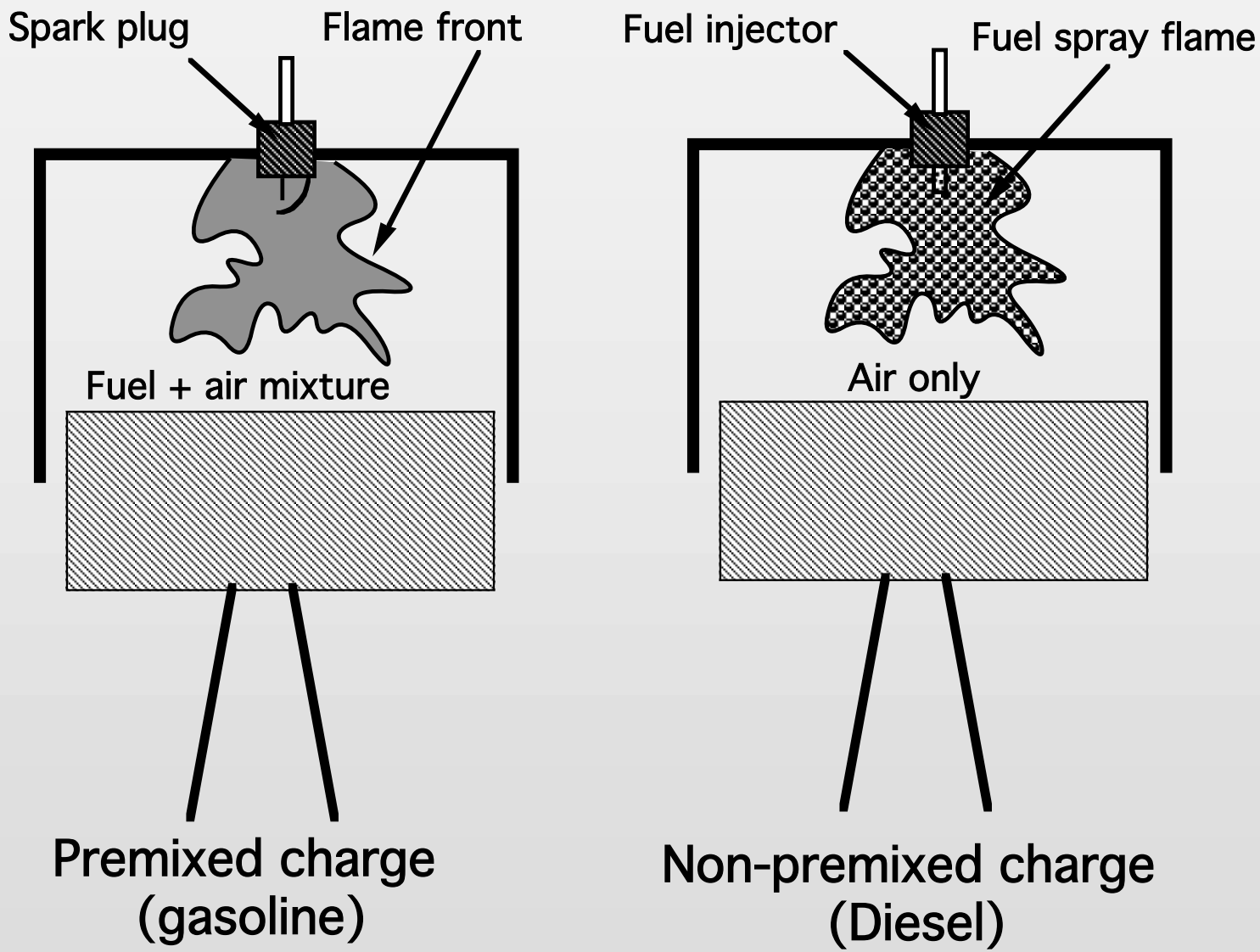
Reciprocating piston engines (gasoline/diesel)





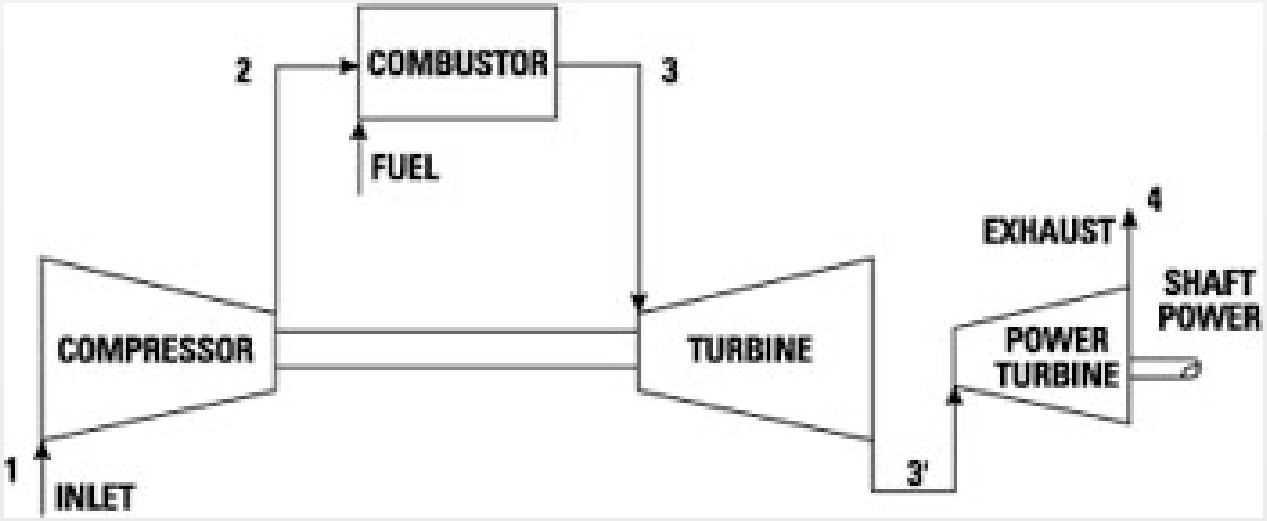
http://www.howstuffworks.com

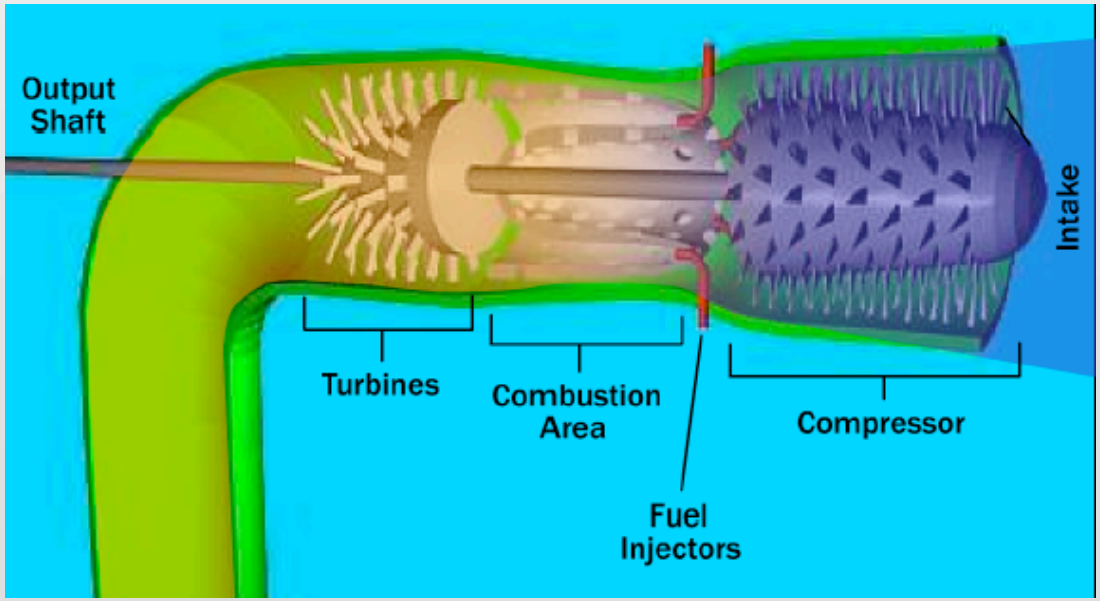
Premixed vs. non-premixed charge engines



Reference/Background Information

Basic gas turbine cycle (Power Generation)



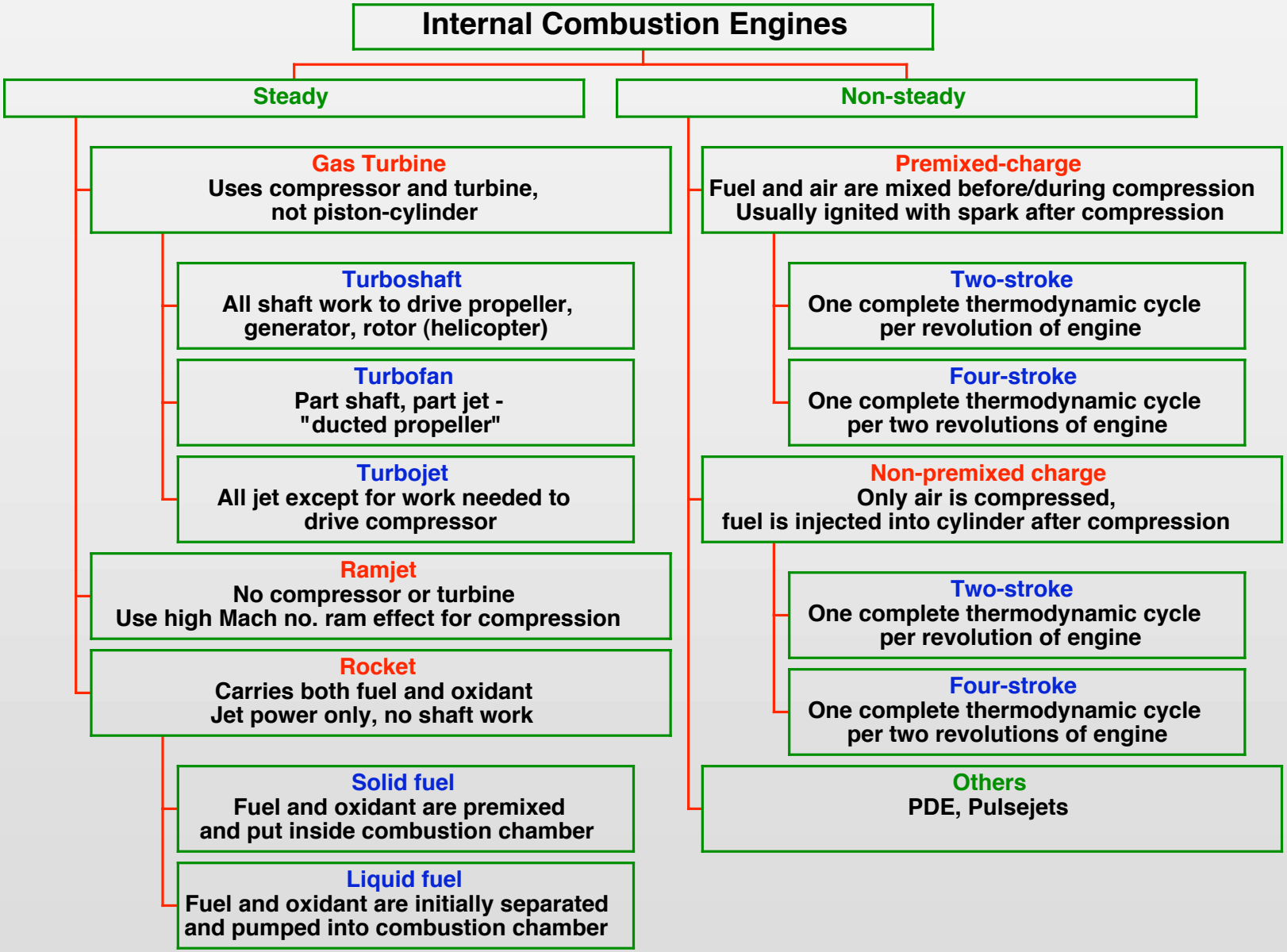


http://www.asme.org/igti/resources/articles/intro2gta.html

Classification of IC engines

- **Internal combustion engines (ICEs)** is generally used for vehicle (car, aircraft, etc.) propulsion
- By definition, ICEs include gas turbines, supersonic propulsion engines, and chemical rockets
- Definition of internal combustion engine: a **heat engine** in which the heat source is a **combustible mixture** that **also serves as the working fluid**
- The working fluid in turn is used either to
  - Produce shaft work by pushing on a piston or turbine blade that in turn drives a rotating shaft or
  - Creates a high-momentum fluid that is used directly for propulsive force

What is / is not an ICE?



Why internal combustion engines?

- Alternatives - external combustion - "steam engine," "Stirling cycle"
- Heat transfer, gasoline engine
  - Heat transfer per unit area (q/A) = k(dT/dx)
  - Turbulent mixture inside engine: $k \approx 100\ k_{\text{no turbulence}} \approx 2.5$ W/mK
  - $dT/dx \approx \Delta T/\Delta x \approx 1500\text{K} / 0.02\text{ m}$
  - $q/A \approx 187{,}500\ \text{W/m}^2$

- Combustion: $q/A = \rho Y_f Q_R S_T = (10\ \text{kg/m}^3) \times 0.067 \times (4.5 \times 10^7\ \text{J/kg}) \times 2\ \text{m/s} = 60.3 \times 10^6\ \text{W/m}^2$ - 321x higher!

- CONCLUSION: HEAT TRANSFER IS TOO SLOW!!!
- That's why 10 Boeing 747 engines ≈ large coal-fueled electric power plant

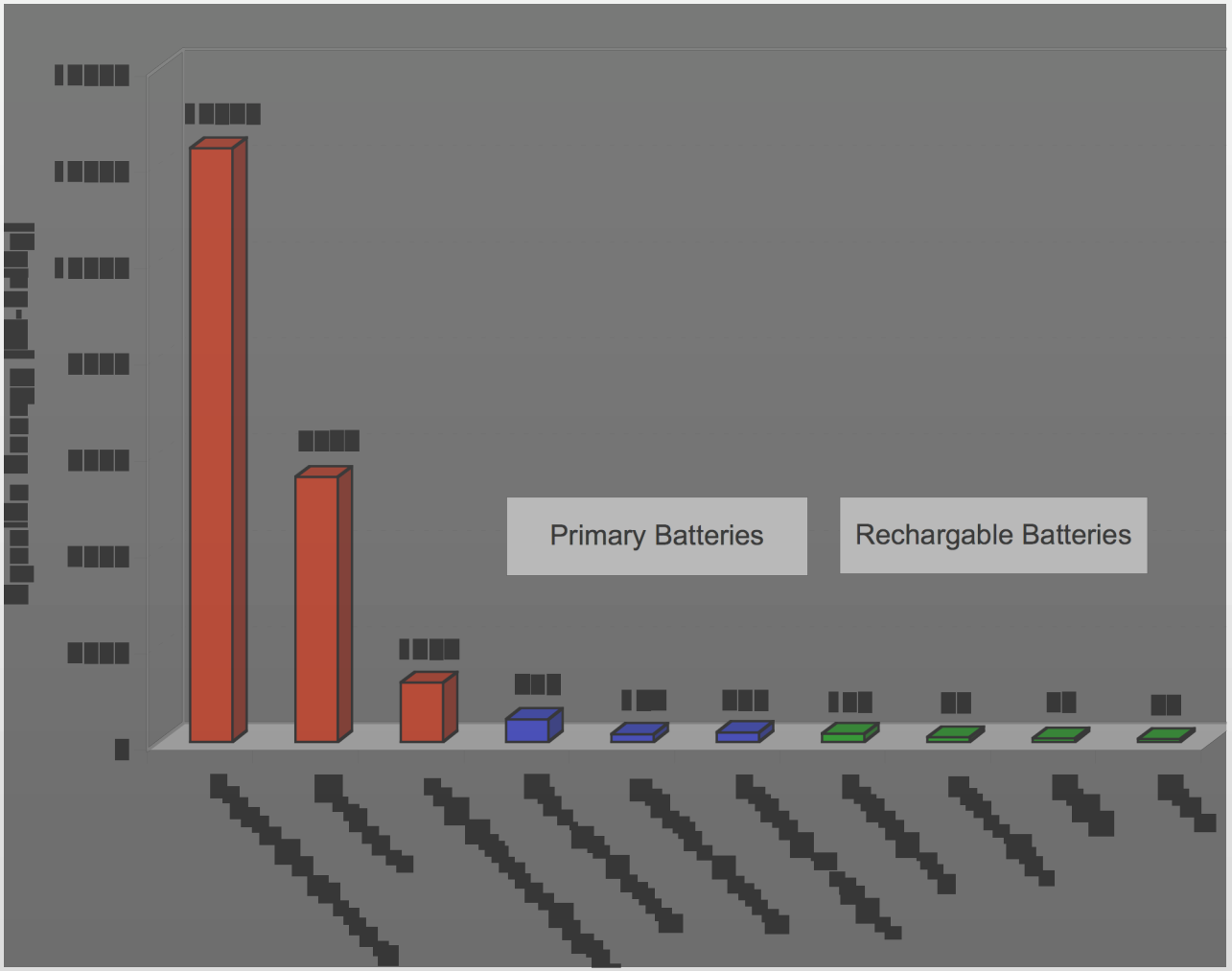
k = gas thermal conductivity, T = temperature, x = distance, ρ = density, Y_f = fuel mass fraction, Q_R = fuel heating value, S_T = turbulent flame speed in engine

Why internal combustion engines?

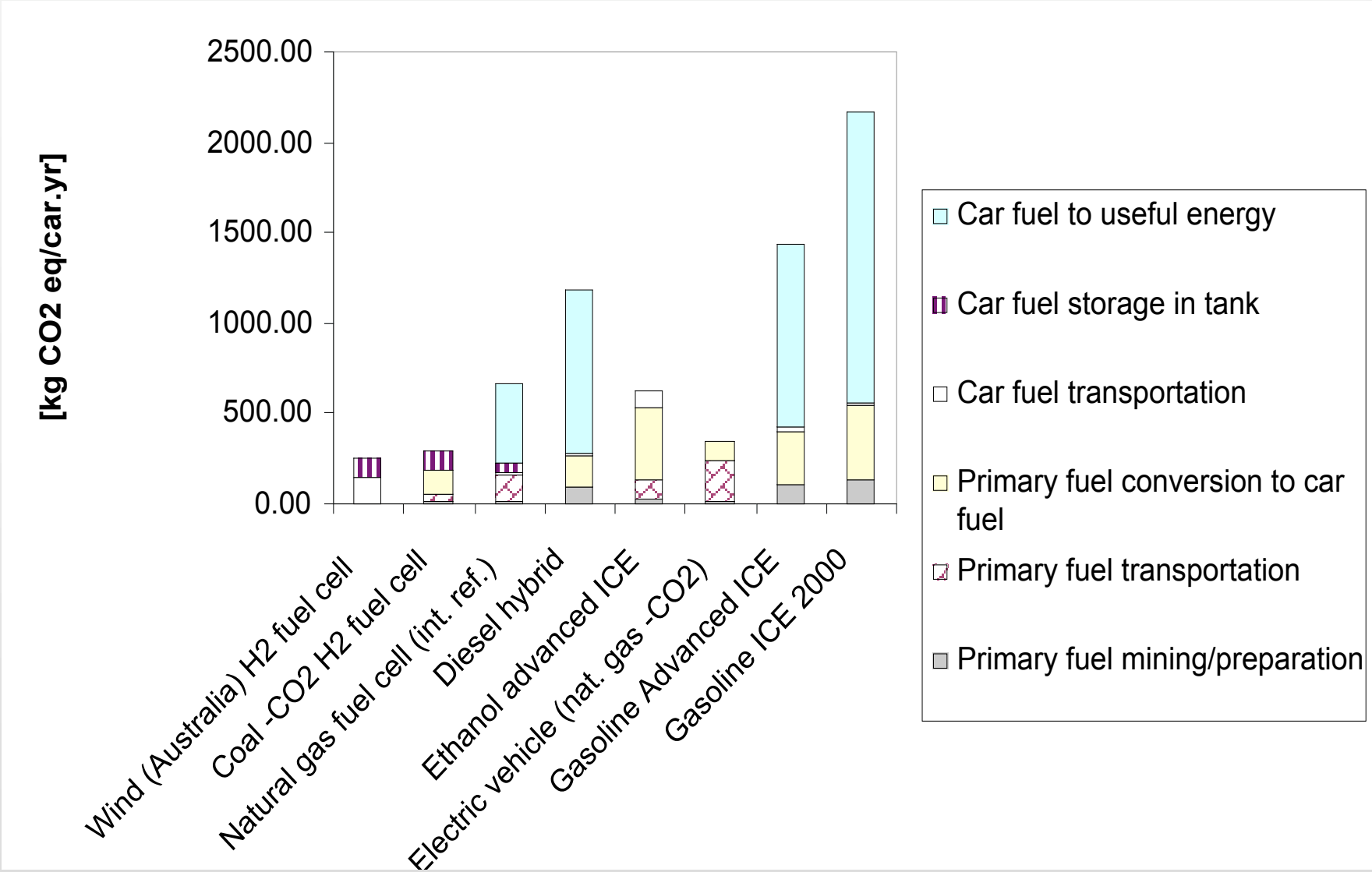
- **Alternatives - electric vehicles**
  - **Why not generate electricity in a large central power plant ($\eta \approx 40\%$), distribute to charge batteries to power electric motors ($\eta \approx 80\%$)?**
  - **Car battery, lead acid: 100 amp-hours, 12 volts, 20 kg; energy/mass = 100 A * 12 V * 3600 sec / 20 kg = 2×10^5 J/kg**
  - **Gasoline (and other hydrocarbons): 4.5×10^7 J/kg**
  - **Factor of 225!**
  - **Fuel cell systems better, but still nowhere near gasoline**
  - **"Zero emissions" myth - EVs export pollution**
  - **Environmental cost of battery materials**
  - **Possible advantage: makes smaller, lighter, more streamlined cars acceptable to consumers**
  - **Eventual conversion of electric vehicles to (hybrid?) gasoline power (>100 miles per gallon)**

"Zero emission" electric vehicles

Power Density



Pollution Generation (More Next time)



Why is it so hard to get people to use new technology?